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SCIENCE AND CHARACTER.*

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The first president of the Indiana Science Teachers' Association, however unintentionally it may have been done, established a precedent which grants each succeeding president the privilege of discussing any subject he may have resting upon his mind. This view was no doubt taken a few years ago when "Science and Culture" was so ably discussed. Also more remotely when "Science and National Character" was presented in an equally admirable manner. I wish, therefore, in connection with what has been said along these very similar lines, to call your attention for a time to the influence a study of the sciences may have in determining individual character. Individual character has been called one of the greatest motive powers in the world. Indeed, it is the power that fashions all forms of institutions and governments and determines their period of usefulness among men.

No institution or government, as is well understood, ever terminated itself by any inherent power of its own, but its termination has always come through the individuals of which it is composed. To build, therefore, for national longevity or national prosperity and greatness is to work within the individual, to place about him such environments as will enable him to acquire for himself that intellectual acumen, accompanied by the kind of moral fiber that fosters national virtue, honesty, and integrity.

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* The President's address delivered before the Association of the Science Teachers of Indiana, May 24, 1903.

The dead nations of the past are striking examples of this truth. As long as the individual was in harmony with the right and labored to uphold and advance the general good, prosperity was a result of the effort; but when the individual became so debased in character that it was impossible to discriminate closely between right and wrong, downfall and decay inevitably followed.

Sound character is necessary not only to national stability, but it is also most essential to individual freedom; freedom from vice and from the degrading results of ignorance and menial servitude. History contains many examples of individuals who were slaves to all forms of masters; slaves to political ambitions, to unbridled passions, and to false social customs. Since history is said to be constantly repeating itself, these conditions therefore exist today as well as in former times. The Skimpoles of society are children still, though believing themselves to be enjoying the greatest individual freedom, while the Calibans are only waiting to "lick the shoe" of some one who is able to grant them favor.

The question naturally arises, How may these conditions be adjusted to be comparable with our highest ideals? The answer, we believe, is in a great measure through the schools. The germs of character come with birth, but the development of the perfect product is wrought out by means of external influences brought to bear upon the expanding life of the individual.

The time appears to be passing when a large number of the boys and girls are longer able, at home and under accompanying influences, to obtain that training which leads to character of sterling worth. As a result of this condition the public is placing more responsibility than ever before upon the teacher in regard to the proper training of its youth, while the parent is becoming more and more a neutral factor. Superintendent Charles R. Skinner, whom we know as the great exponent of moral training in the schools, has called attention to this fact in that "formerly we relied chiefly upon the home and church to train our youth along ethical and moral lines, the recognized province of the schools being to give intellectual training and incidentally to supplement the work of the other two agencies, rather than to take the initiative. But there seems to be," he further says, "a continual transition in progress, by which

the former function of church and home—as related to moral and ethical training—have more and more devolved upon the schools." The causes producing these conditions it is not the purpose of this paper to discuss, but that they exist is sufficient reason why effort should be made to meet them.

Not only the demand of the parent is becoming greater, but also that of the business world. Recently a circular letter was sent out by the New York State Teachers' Association to the leading professional and business men of New York City, relative to the kind of training boys should receive which would best fit them for useful employment. Over four hundred replies were received in which these men were unanimous that in training to this end "great stress should be laid upon character building upon the training of the morals and manners and inculcating an ability to follow instruction."

There are various means in the school of developing character. Its general atmosphere has an ennobling or depressing influence upon its members. The bearing of the teacher; his quiet and impressive manner; his keen and unfailing interest; his firm yet guiding hand, all have a potent influence for good along this line. Again, the companion-choosing power of the pupil is a feature of no small consequence, and should be carefully directed by those who have a longer range of vision than the average pupil has in such matters. How often boys and girls enter the high school with a stock of ability valued above par and go completely to pieces because of the selection of companions, not necessarily vicious, but whose habits of study were loose, and whose general bearing was not in harmony with the best interests of the school. These things, together with many others that might be named, constitute the environments of the pupil, all of which have a powerful influence in shaping character.

One of the greatest sources of power, however, to this end comes through work; through the formation of habits to persistent and rigid effort. Work has been called one of the best educators of practical character. It evokes and disciplines obedience, self-control, attention, application, and perseverance. It matters not so much what the work may be, whether manual or intellectual, if it is

good, true, honest effort, done with an enthusiastic interest, it leaves a lasting impress upon the worker. The boy who has not made a collection of stamps or old coins, or who has not observed the nesting places of birds and the things upon which they feed, has lost something from his makeup that can not easily be restored.

Much discussion has taken place of late in regard to the relative value of the different subjects of study in the curriculum. This is no doubt due to the fact that it is impossible to study all, although there are many constructionists who seem to regret the fact that there are so few and hope that others might yet become available. It must be admitted, however, that some subjects possess greater developing power than others, yet anything that calls forth the attention and interest of the learner, whether it be the jingle of the nursery rhymes or the study of differential calculus, or anything between these wide extremes, it never fails in the development of that power which goes to make character.

There is a tendency on the part of many teachers to regard the subjects which they teach as the most far-reaching in its culture and disciplinary value. This is certainly not the broadest view of the question to be taken. There are, however, so many educators and writers of prominence who have held such decided opinions, on one side or the other, as to whether classical or scientific training is of more worth, that the question is always a very interesting one.

The January and February numbers of *Education* contained a very excellent paper on "The Advantages Which Accrue from a Classical Education." While the writer would not advise the removal of any subject from the curriculum, yet the greatest emphasis is placed upon the "paramount advantage of a classical education for any profession or vocation in life." As a conclusion the writer states: "If it is true that education is not a knowledge of practicability, but a development, and with the help of eminent scholars we have reasoned correctly that this is best gained by the Greek and Latin authors; that they give the greatest appreciation of the English language and literature, and best fit one for all the responsibilities of life, then must we not conclude that the advantages which accrue from a classical education are far superior to those of any other?" Goethe and Schiller, Mathew Arnold and other English

writers, together with many college men of today, are quoted as believing strongly in the superiority of the classics as subjects of study, and the opinions of such men are not to be ignored. But we have scores of men equally as strong—and this is what gives the question its decided interest—who hold the opinion that the sciences, if properly studied, will result in all the good that can possibly be obtained from the classics and more.

Tyndall and Alexander Bain, as every one knows, were both anti-classical in their views. Each regarding that the training obtained from a study of Greek and Latin was obtained at too great a cost, also that the student, for the length of time usually devoted to these studies, is not duly impressed with the thoughts of Greek and Roman writers. The attitude taken upon this question by Herbert Spencer, Agassiz, Kelvin and Jordan are too well known to here receive more than a passing reference.

Dr. Ernst Mach in his recent book of Scientific Lectures—one of which has for its subject, "The Relative Educational Value of the Classics and Mathematico-Physical Sciences in Colleges and High Schools," has certainly treated the subjects fairly and impartially, as might be expected from a man of his breadth of culture. Yet he says, "more strongly than ever are authoritative voices now raised against the preponderance of instruction in the classics and in favor of an education more suited to the needs of the times, especially for a more generous treatment of mathematics and the natural sciences." In pointing out the necessity for a study of these subjects, he says that "without at least an elementary mathematical and scientific education a man remains a total stranger in the world in which he lives, a stranger in the civilization of the time that bears him. Whatever he meets in nature or in the industrial world either does not appeal to him at all, from his having neither eye nor ear for it, or it speaks to him in a totally unintelligible language." In dwelling upon the value that comes to the young student from scientific study he lays special emphasis upon the influence these studies have in strengthening the reasoning and judging faculties and giving vigorous exercise to the imagination.

It depends in a great measure upon the inclinations of the

student; upon the general bent of his mind, as to what course he shall pursue. If he has a natural dislike for the classical language and is unable to place himself in more agreeable relations with that kind of work, then his development may best be accomplished by devoting his attention studiously to other lines, to those in which he takes the greater natural interest. The sciences usually offer such a field as this. A very small percentage of the boys and girls who take up the study of any branch of science ever find it a tiresome line of work, for which reason it becomes a most valuable instrument in the development of the individual.

George W. Earle, in the vice-presidential address before the Eastern Association of Physics Teachers, has said, "What could assist in character building more than hard and honest work in the laboratory at some difficult quantitative experiment where the pupil must rely upon his own efforts and depend for success upon truthful observations, accurate readings, and a strict following out of directions?" "Does not every laboratory teacher," he further says, "feel from his own experience that no subject taught in the public schools has greater influence in training pupils to thoughtfulness, reliability and to the importance of obeying orders than the study of science?"

The most important acquirement, however, in science teaching is a true scientific spirit; without which, on the part of the pupil, the efforts of the science teacher will fall largely upon barren soil. This expression has been used so often by scientific men that it possesses a degree of triteness, yet it means so much and conveys the meaning so well of that which is desired, that we may not expect it soon to become obsolete. Many attempts have been made to define the term, but it has been found a difficult task. It is, however, we believe, to learn the language of nature, to know the truth as found in nature and not in books, and to possess a thoroughness in the work at hand. It induces the student to seek the laboratory at the earliest possible moment, to remain there as long as other work will consistently allow, to devote an undivided attention to the requirements of the problem and to become actually forgetful of self and surroundings. Such a spirit as this goes far beyond the mere handling of apparatus because

it is odd in its construction, or the careless accumulation of data from which may be drawn erroneous conclusions. It has for its results the proper development of those peculiar characteristics which in the end makes a man a man.

The sciences are peculiar in the development they offer, and differ from most other subjects of study in that they employ the hands as well as the mind. How true it is that in many other subjects one may read a page and on having completed it may be forcibly impressed with the fact that he knows little or nothing of its contents. This is especially true of boys and girls whose minds are not yet trained to any degree of concentration. The permission thus granted the mind to go astray will in time result in habits most detrimental to the pupil.

With the sciences this is rarely the case. The work demands such constant attention in first obtaining a clear conception of what is to be done and then in the proper arrangement of apparatus and the collection of data, that the mind has little time, if indeed it should have the desire, to run away from the work in hand. Any subject of study that may thus tend to discourage rather than to foster these mental aberrations is certainly fruitful in the kind of development desired.

One of the faculties of the intellect which has a most important bearing upon the character of the individual is the imagination. By means of it he is constantly forming new ideals of life, ideals of what he may hope to be, ideals which he may never reach, but without which it would be impossible for him to be even what he is.

The imagination is influenced by what it feeds upon. If it grovels in the lower forms of thought, the ideals of its creation are mean and ignoble. If it soars to loftier heights, they may be pure and sublime. The mere fact that the individual possesses these ideals of a pure and noble type raises him above the lower levels of his nature and places him in a realm of beauty and purity of thought. Every activity of the mind is developed by being brought into activity, the imagination being no exception to the rule, and that upon which it delights to dwell has a reflex influence in that it tends, if good, to make it still loftier in the

products of its creation. The poet is master over the image world which he creates only because of the familiarity which results from long continued practice in calling up its objects and molding them at his will.

The poetic mind finds in nature endless forms which readily become symbols of thought and feeling; insensate matter is transformed into living objects by the magic touch of the poet's genius. Shelley, Wordsworth and Byron loved nature, and they found in her not only a realm of delightful pleasures but a powerful stimulus to their imaginations which enabled them to express their thoughts in such poetic beauty. Nature is varied in her mood and appeals to all the varied temperaments of men. She is joyous for the gay, sad for the sorrowing, beautiful for the aesthetic, sublime for the strong and courageous. So in the differences of character between man and man we see their attitude toward nature. Wordsworth was a dreamer. He lived under the "habitual sway" of nature and admiring the beautiful as he did, found it in nature's most insignificant objects, as the violet, daisy and buttercup. "To me," he says, "the meanest flower that blows can give thoughts that too often lie too deep for tears." These small things he regarded as worthy of his poetic art and described them in beautiful phrases.

Byron, on the other hand, was intense in everything he said and did. He passed unnoticed the flowers, the rippling waters and the quiet shade, around which many other poets of nature love to linger, and devoted his thoughts to majestic mountains, ragged moss covered rocks and rushing waterfalls. We discern his attitude toward nature in lines like these:

"The horrid crags by toppling convent crowned,
  The cork-trees hoar that clothed the shaggy steep,
The mountain moss by scorching skies imbrown'd,
  The shrunken glen whose sunless shrubs must weep,
The tender azure of the unruffled deep,
  The orange tint that gild the greenest bough,
The torrents that from cliff to valley leap,
  The vine on high, the willow branch below,
Mix'd in one mighty scene, with varied beauty glow."

Shelley's treatment of nature may be said to combine both the sublime and beautiful. His verse has been compared to the "ever changing movements of an oratorio by one of the old masters of the sublime, now grand and majestic as the rolling of the spheres, fiercely sweeping as to the clang of trumpets, as if heaven were at war, anon hurrying impetuously onward like the dashing of a mountain torrent, and at last subsiding into the gentle murmur of the brook, laughing amid bees and flowers, and listening to the fairy warbling of the birds."

While these represent the various attitudes of the poet toward nature, yet these very attitudes are for the most part produced by the influence that nature has upon the mind of her constant devotee. Shelley himself in "The Revolt of Islam" very beautifully points out the various aspects of nature which early had a marked influence in molding his young imagination.

Every hypothesis and law of science is the result of vivid imagination. Newton's mind passed from that historic apple to the moon, and assuming that it also fell toward the earth, later calculated exactly how much that fall amounted to per unit of time.

The geologist requires a vivid imagination in the construction of prehistoric forms and geological ages. The discovery of a planet; the construction of an entire skeleton from a single bone; the invention of a machine that seems to possess almost the intelligence of man; all these are the results of an imagination of only the rarest keenness.

That which is a result of the mind's activity, as before stated, may have a reflex influence upon the mind to further increase its power. This follows not only to the author of these conceptions but to anyone who may studiously pursue them in their various relations. It follows then that scientific study is most efficient in the development of imaginative power, and if this kind of work is pursued with joy and gladness by the pupils of our schools, it will ever result in higher and nobler ideals of life.

The imagination, however, must at all times be held subservient to reason, else it becomes fantastic in its creations, in which case true scientific progress becomes impossible.

Since this relation exists between these two faculties of the mind, and the former is so strongly influenced by scientific pursuits, it might be asked whether the latter is equally quickened. The ability to reason well is one of the essential requirements of scientific study and since the relations between scientific phenomena are usually more obvious than between those of many other lines of work, science becomes a valuable instrument in disciplining this faculty of the mind.

It is claimed upon good authority that an intelligent study of Darwin's "Origin of Species" is not inferior to a study of elementary geometry, and in one respect it is regarded as superior from the fact that the reasoning of natural science is more nearly akin, than that of mathematics, to the reasoning of practical life. All laboratory work, in whatever branch of science it may be, if properly executed requires a process of sound reasoning to accomplish any definite ends. A logical interpretation of the observed phenomena is always necessary in order that the greatest value may be obtained from the experiment.

A study of the sciences is also most efficient in developing the judgment of the individual. Judgment in fact lies at the basis of all science. The sciences are developed by generalization and reasoning and judgment is involved in both of these. No scientific thought would be possible without the faculty of the judgment.

It should therefore be one of the leading objects in the training of young people to aid them in acquiring the habit of forming judgments. They should be trained to see things in their relations and then to put these relations into definite propositions. Faraday has said that the most common intellectual fault is a deficiency of judgment. He further claims that society is not only ignorant in regard to the education of the judgment, but that it is ignorant of its ignorance. The cause of this state of things he ascribes to a lack of scientific culture. We dare not question this conclusion when we bear in mind the fact that a correct judgment of all surrounding events and consequences is possible only in so far as we have comprehensive knowledge of the way in which surrounding phenomena depend upon each other.

The method that science offers of drawing conclusions from data and—taking nothing for granted—verifying these conclusions by rigid experiment is a source of discipline of great value to the judgment and reasoning power of the pupil.

A strong will is also essential to a high and noble character. We admire the man of clear cut opinions and unfaltering purpose, and detest, or rather pity, the man who is always guided by the opinions of others. A bold and courageous rascal has some traits of character more to be desired than those of a cowardly and vacillating saint. One element of greatness in the president of the United States and the reason he is so greatly admired by even his political opponents, is his high sense of justice, and his unwavering determination in carrying out his convictions even in the face of all opposition.

That which rightly cultivates the will power of the individual then, tends to give strength and dignity to character.

Nature study may not be as proficient in this kind of development as the mathematical sciences, but the latter certainly hold first rank in the cultivation of this faculty of the mind. There is hope for the future of a boy who applies himself to a lesson simply because it is difficult, who refuses aid, and is willing to study late at night rather than be defeated in the undertaking. Such as he is cultivating a force of will that will be of inestimable value in after life. Prof. D. W. Dennis has said, "The fact that our first and last presidents were brought up in wealth, while Lincoln was reared in poverty made little difference in the outcome. Wealth and poverty were both accidents. It was work that made the men." Hard mental labor beset by many difficulties; delays in experimental work for something to transpire or be completed, and painstaking repetitions, because of inaccuracies in previously determined data; all these require efforts of the will, the result of which, along with moral goodness and sound judgment, will produce a successful worker in any field.

Away with the nonsense that school work should be made easy, and that the boys and girls should be allowed to have a good time, as some school men would fain teach. Nothing is more debilitating to the character of the pupil, or more detrimental

to the proper government of the school than methods of this kind. The work should be made interesting and highly attractive but it should have enough of severity about it to command respect and be worthy of the time and attention of the pupil.

A study of the sciences also furnishes sound ethical training. It teaches accuracy, neatness, promptness and integrity. All of which are not only essential to sound character but also to the highest success in life. It is true that science study will not reclaim a depraved nature, but any student who may come into possession of the true scientific spirit, the spirit of unselfish, honest and thoughtful truth seeking will experience a general moral uplifting.

E. Benjamin Andrews in speaking of the great need of true moral character on the part of the individual, and in pointing out the means for its proper development, has said: "True scientific study is rich in moral promptings. Instance the love of right for right's sake, the idea of simple truth, irrespective of consequences, which has come into being almost solely from the inculcation of exact science. This is a result for which those who love righteousness should be grateful to the positive philosophy. In this respect the positivists have, without thinking of it, become powerful ethical teachers. They have insisted, as has never been done before, upon the importance of laying aside prejudice and interest, and getting at simple, unalloyed facts. There has been called into existence thus, a new, distinct and most beautiful form of the love of truth. This noble phase of virtue is emphasized and nourished today in every scientific laboratory and classroom throughout the world." Truth is the foundation of the whole superstructure of science. The latter is so exact in all her methods of operation that to the thoughtful mind is afforded a constant source of admiration.

This exactness made it possible for Le Verrier, after careful mathematical calculation, to say to a working astronomer, "Point your telescope to a certain small area in the heavens, within which you should find a new major planet." He did so and, marvelous as it may seem, Neptune was within the telescopic field. It also made it possible for Pasteur to inoculate twenty-five sheep from

a flock of fifty with attenuated virus of anthrax, and in a few days inoculate the whole flock with unattenuated virus and exclaim, "At a certain time tomorrow the twenty-five sheep which had not previously been inoculated with the attenuated virus will be dead, while the others will be grazing in the pasture." The time for the test arrived and, to the surprise of all, the truth had been foretold.

These are but two of the many illustrations that might be given to show with what unerring exactness nature executes all her decrees. There are no shams in nature; all is truth. The flower that blooms where feet have never trod has just as sweet perfume, and is just as beautiful to the eye, as any in the public gardens. There are roses on the other side of the bush as well as on the side next you. The lark that sings in the face of the sun sings just as sweetly as it would within our range of hearing. This is not always true in the affairs of life. Here shams creep in not only where convenient, but where it is at all possible. There are shams in politics, shams in "courts of chancery," shams in art and architecture, and shams in social customs. On Indian ridge and at the base of it in Mt. Auburn cemetery in Cambridge, Mass., lie the remains of our great poets, Longfellow and Lowell. These graves are marked by the plainest of marble slabs. In view of these sacred spots, but a short distance away, is erected a grand mausoleum of costly marble over the remains of a liquor dealer of very small renown. As one stands in silence and views these different graves, he is impressed with the truth that the good these men have done in the world bears an inverse ratio to the amount of marble that marks their last resting place. Longfellow and Lowell need no monument. Their monuments have been erected in our hearts and lives, while on the other hand some colossal structure is essential to perpetuate even a memory.

In the last place, the youths of our schools may form more sturdy characters by a careful study of the lives of scientific men. President Thwing has said "We should read great books of great men." If we are able to influence those under our instruction to follow such advice as this we shall have accomplished something

that will be to them an everlasting joy. But to fail even here is to fall short of one of the many privileges of the teacher of science in the development of pure and noble lives.

Very recently the writer made some investigations as to the kind of reading the members of his classes had done within the last few months and found in almost every case that the strongest in scholarship and the most trustworthy in the school were able to present the best list of books. It is very reasonable to conclude that this is true not because they are the strongest in the school, but that they are the strongest in the school because, along with other things, they have acquired a taste for this kind of reading.

To read and study the lives of men who have accomplished something by hard and honest toil inspires one to greater effort, and encourages the formation of higher ideals in life. The scientific characters of history who stand out before us with any degree of prominence have been indefatigable workers. Faraday, when asked the secret of his success as a scientific investigator, replied: "The secret is comprised in three words: Work, Finish, Publish." The secret of Edison's fame is his unremitting toil and his persistency in carrying a thing to some definite end. Darwin has said in a letter to his friend, Mr. Fox: "I was wishing to hear about you, but have been in such an absorbed, slavish, overworked state, that I had not the heart without compulsion to write to anyone or do anything beyond my daily work."

The mottos or maxims of men often reveal their characters. The motto of Sir Walter Scott was "Never to be doing nothing." And that of Voltaire, "Toujours au Travail."

The claim that the pupils of our schools are over worked, especially those of the high school, is the greatest scholastic nonsense. This view, however, is taken not so much by those who have the supervision of the work, or by the broader minded class of parents, but by those who over indulge their children in seeking lines of the least resistance and in forming habits that dissipate their energies. A few, it is true, do drop out of school who are physically incompetent to further continue their work, but upon investigation it is found that ninety-nine per cent of those who are compelled to thus leave the ranks do so because of out-

side disturbances, rather than good wholesome and well regulated study.

Again a study of the lives of men of science will teach patience, cheerfulness and simplicity. These traits of character were very marked in Galileo, Laplace and Newton, Berzelius, Liebig and Dumas.

Who can study thoughtfully the lives of Agassiz or Pasteur and, discovering there such matchless elements of character, not be lifted to a higher plane of living? A comparative study of biography will show conclusively that immorality has not held much prominence in the ranks of scientific men. Far less than among men whose lives have been devoted to literature and art. These may arouse the baser passions, but scientific truth is never impure. In conclusion then, is it wise to regard any one subject of study as alone suitable to furnish the proper development in the lives of our pupils, or does it show a fullness of vision on our own part to conclude that the subject which we teach is of "paramount" importance in this developing process? But rather shall it not be said that good, honest, unselfish and persistent effort in any line, so far as work is concerned in the question, is one great means at least of determining good, strong, stalwart, honest character in the boys and girls of our American schools.

IN THE CLASS ROOM.

BY GEO. D. HUBBARD,

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Class room instruction has undergone a considerable transformation during recent years. In fact, what was once almost the only method is now all but discarded, while different plans scarcely thought of a few years ago are rapidly superseding it. At least two causes appear for this change: one, a change in the subject matter taught, the other, a change in the attitude of the teacher toward his work. Once only those subjects were taught which had been thoroughly worked over, discussed and written upon for years. Now much of the subject matter in the sciences is the result of research during the last ten years, and every twelve month contributes its items to the general fund of knowledge, while every aggressive teacher must correlate the items and reduce them to their places in the sciences. Today investigation or the laboratory method is the rule while formerly the student was only required to commit to memory what others had worked out. Now the teacher allows the student a very free rein in the matter of opinions and conclusions, and often even in what he studies merely directing the work, while in past days the student was expected to do and to think as did his teacher.

Once the teacher presented his own personality to the student. He inspired by his own purpose. His influence was a dominant factor in his results.. Now the profession has less of dignity and the pupil less of respect for it, hence personal influence is not nearly so great an ingredient in the pupil's education. Pupils rarely aim or wish especially to emulate their teachers but they do want the truth that will help them to win in the world. Formerly facts were taught, now the methods for acquiring the facts are taught. The movement from one ideal to the other is so complete and the ends so antipodal that the change may be likened to the swing of the pendulum from one end of the arc to the other. Which end of the arc represents the highest ideal is at present immaterial. The pendulum swings, acting and reacting, but never settling down into one steady course. In many ways the

swinging is helpful. In the aggregate the changes will prevent stagnation in our work.

With the new subject matter and the new attitude of pupil and teacher to the former and to each other have come many new class room methods whose value is being determined by use.

Text book assignments alone and verbatim recitations are rare where once they were common; collateral readings with reports form an increasing factor in the scheme of many teachers. For subjects whose material is widely scattered through the current literature, the lecture system plays a large part; a method especially developed when the teacher is inclined by nature and permitted by his work to keep thoroughly abreast of the times. The purely inductive or laboratory method is in high favor. The disputation or Socratic method so valuable as a thought stimulator, and so full of work for the teacher, is still in vogue in some class rooms. It should be in all.

The reception of these various methods varies. Pupils criticize every method. One scheme suits this set while another is popular with a second set. Many students are attracted to a well presented lecture course, because it puts new, live material in a clear, orderly way; but few students, except the more advanced in colleges, seem able to retain and reproduce in proper relations the facts so set forth. It has been our experience that the student, even though he takes notes, does not get the mastery of his subject until he has put it into his own words and has himself given it expression. One can scarcely be said to know a thing unless he can tell it. The psychologist teaches that repetition fixes a fact; and that repetition under the strain of class room attention is still more effective.

Of course the more advanced the student becomes, and the more experience he may have had in telling what he knows, the less the real need of the teacher as questioner. The pupil learns to question himself. But the earnest student during his high school, academic and college work welcomes the careful questions. I should like to see in many class rooms a more exalted position given to the question and answer method. It means more work for the teacher, but it also means better results to the pupil. Let the

teacher study with a view to questioning; seek questions that develop discussions, and those that bring out relations of related things. Rarely spend the time asking questions that can be answered by yes or no. Make the questions short, clear and logical but do not color them with personal opinion. There is a time to impart personality but it is not in the question. Try to get at what the student *thinks* about the matter, and what he does not know as well as what he does know. Under fire of questions he should find a more comprehensive viewpoint.

There is such a thing, however, as trying to lead a student where his knowledge is insufficient to follow, but a wise teacher will usually avoid such territory. Childish and abstruse questions are alike to be avoided. Simplicity and clearness do not militate against depth. In fact without both no very great depths can be reached. Questions should not be labored or fraught with weighty rhetoric, but should be conversational, personal.

Lectures by teachers and reports by pupils should have their places in the class room; but they serve their purpose better if they, like the text book assignment, are followed by the quiz.

PHYSICAL CHEMISTRY.

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Chemistry may be studied from two standpoints. We may investigate the subject with a view to discovering all the possible chemical compounds and of becoming acquainted with their properties. This may include also the study of chemical reactions in so far as some compounds are decomposed and others formed. This branch of chemistry may be called *descriptive chemistry.*

Again, the subject may be approached with a view to discovering the laws governing chemical phenomena and of examin-

ing and testing the various theories that have been proposed from time to time to account for these phenomena. This branch of chemistry may be called *physical chemistry.*

Because we have heard so much of physical chemistry in recent years many of us are led to believe that this is a new branch of the science. This, however, is not the case. The term may be comparatively new, but a little consideration will show us that much of the material is comparatively old. From the time that men began to study chemistry in a scientific way they have endeavored to discover the laws governing chemical action. Many of these laws were discovered, many generalizations were reached, and many theories were advocated long before the term "physical chemistry" came into common use. The three fundamental laws of chemistry were discovered a hundred years ago. Early in the last century the common laws of gases, liquids and solids were recognized. Before the middle of the century many investigations had been carried out with a view to the systematic study of the physical properties of chemical compounds and these investigations had resulted in the discovery of the fact that, in the organic compounds, at least, equal differences in chemical composition correspond to equal differences of physical properties. Pasteur made his important observation on the relation between the composition of the tartaric acids and their power of rotating the plane of polarized light fifty years ago, and a further study of the relation between this rotatory power and chemical composition, leading ultimately to our present theory of the asymmetric carbon atom and the arrangement of atoms in space, was made twenty-five years ago.

Again, to speak of another physical property, it has been many years since the heat relations in chemical reactions became the object of study, for Hess discovered his law of the thermoneutrality of salts as early as 1840. Berthelot began his elaborate thermochemical investigations in 1865, while Julius Thomsen began the publication of his accurate thermochemical measurements in 1882.

Then again, the study of the electric current in connection with chemical reactions practically began with the work of Sir

Humphrey Davy in 1801; the electrochemical theory of Berzelins, the only one to be generally accepted, appeared soon afterward, while the electrolytic law of Faraday was published in 1834. An extensive study of the relative velocity with which ions travel when solutions are electrolyzed was made about 1852, while Kohlrausch's simple method of determining the conductivity of solutions was devised in 1861.

Finally the study of the relation between the amount of a compound brought into play during a chemical reaction and the extent of that reaction, in other words, the study of chemical dynamics, is nothing new. The celebrated French chemist, Berthollet, made extensive investigations in this field in the early years of last century; the law of mass action, known as *Guldberg and Waage's Law,* was published in 1867, while Willard Gibbs made a general application of thermodynamics to conditions of chemical equilibrium as early as 1872.

From the sketch just given it will be seen that physical chemistry—that branch of chemistry which treats of the laws and theories governing chemical phenomena—is no new thing. Why, then, one may ask, all this commotion about physical chemistry? Why are so many text books on the subject now being written? Why are so many professorships being established in order that the field may be cultivated more extensively? What is this El Dorado to which chemists are flocking? What new discovery has excited their enthusiasm and stimulated hopes of so much reward?

The renewed interest in physical chemistry began a few years ago when the true interpretation was made of certain phenomena observed in connection with the study of solutions. The basis of modern physical chemistry, then, is the modern theory of solutions. It is the object of this paper to review briefly the development of this theory and to indicate a few of its more important applications.

To begin with a very simple illustration, let us imagine a glass cylinder partially filled with an aqueous solution of sugar. Now let us carefully introduce on top of this solution a layer of pure water. As is generally known there will immediately begin a movement of the sugar particles into the pure water and this

movement will continue until the concentration is constant throughout the liquid. This phenomenon was discovered in 1815 and is commonly known as diffusion. It will be observed that there is manifested here by the particles of sugar in solution a tendency similar to that manifested by the particles of every gas, namely, the tendency to scatter themselves uniformly throughout the medium in which they are placed.

Let us take another case. Instead of placing the pure water in direct contact with the sugar solution let us imagine placed between the two a porous membrane of such a nature as to admit of the ready passage through it of either the sugar particles or the water particles. Again it is generally known that the sugar particles will pass through the membrane out into the pure water and that this movement will continue until the concentration of the solution is uniform throughout the liquid. This phenomenon is called osmosis. It will be observed that in the two cases selected the tendency of the dissolved substance to pass into the pure water is the same. In neither case is it checked by any insurmountable obstacle and consequently we have no way of measuring the force of this tendency, if indeed it be capable of measurement at all.

Suppose, now, that we interpose between the solution and the pure solvent a partition which is not permeable by the sugar particles but is by the water. Water from the outside will immediately begin to pass through the partition into the solution, and unless the partition is very strong it will soon be observed that sufficient pressure is developed within the vessel to break it. This pressure is commonly known as osmotic pressure and was first observed toward the close of the eighteenth century. However, the facts were forgotten, but were again discovered in 1815, again forgotten, again brought to light in 1822 in Germany and again in 1827 in France.

While the above phenomena have long been known, no systematic investigation of osmotic pressure was made until 1877. In that year the botanist Pfeffer succeeded in preparing semipermeable membranes by filling carefully prepared clay cells with a dilute solution of potassium ferrocyanide and allowing them to stand for several hours in a dilute solution of copper sulphate. The pre-

cipitate of copper ferrocyanide evenly deposited within the walls of the cup serves as the semipermeable membrane. If such a cup be completely filled with the sugar solution, then closed with a tightly fitting plug carrying a glass tube, and the vessel completely immersed in pure water, the water will pass through the walls of the vessel and rise in the tube and this process will continue until a definite maximum pressure is reached. Since a column of tubing many feet in height would be required to measure the osmotic pressure of even dilute solutions, this method is not used; instead of it a short tube connects the cell with a manometer and the pressure is read off directly in millimeters of mercury.

With an apparatus of this kind Pfeffer succeeded in demonstrating:

First, that osmotic pressure is dependent upon the nature of the substance in solution.

Secondly, that it is directly proportional to the concentration of the solution.

Thirdly, that it varies with the temperature.

However important these conclusions may have been from a botanical standpoint, they had little significance for chemistry before 1885. It was in that year that Van't Hoff, a prominent chemist of Holland, began to develop a theory of solutions on the basis of the above phenomena. After considering Pfeffer's results, he soon observed that the relation between osmotic pressure and concentration is for solutions exactly what the relation between pressure and volume is for gases. In other words, Boyle's law for gases applies to substances in solution.

Again, Pfeffer discovered that the osmotic pressure increases with rise in temperature. Reducing observed temperature to absolute temperature, Van't Hoff pointed out that, concentration being constant, the osmotic pressure is directly proportional to absolute temperature. This is equivalent to saying that the relation between osmotic pressure and temperature is for solutions exactly what the relation between pressure and temperature is for gases. In other words Gay Lussac's law for gases also applies to substances in solution.

There was needed but one more deduction to show the complete analogy between a substance in the state of a gas and a substance in solution, that was to show that Avogadro's law for gases likewise applies to solutions. This was made in the following way: Pfeffer showed that a 1 per cent solution of sugar exerts an osmotic pressure of 521 mm. at 13.2°. Since osmotic pressure varies as absolute temperature, at 0° it would exert a pressure of 496.9 mm. Now since the molecular weight of sugar is 342, a gram-molecule of sugar of 1 per cent concentration would occupy a space of 34.2 liters. A solution of this kind, then, that is, a solution containing a gram-molecule in 34.2 liters, exerts an osmotic pressure of 496.9 mm. at 0°. Now a gram-molecule of a gas under standard conditions of temperature (0°) and pressure (760 mm.) occupies a space of 22.38 liters. Since pressure varies inversely as the volume, if the gas were expanded, temperature remaining constant, until it occupied a space of 33.4 liters, the space occupied by the sugar solution, it would exert a pressure of 497.3 mm. In other words, when a gram-molecule of sugar is dissolved in water and diluted to 34.2 liters it exerts an osmotic pressure of 496.9 mm., while a gram-molecule of a gas occupying the same space exerts a pressure of 497.3 mm. The agreement between the two numbers is sufficiently close to leave no doubt but that Avogadro's law for gases does apply to substances in solution.

From these considerations Van't Hoff concluded that substances in solution are of the same nature as substances in the gaseous state. In other words, when a substance is dissolved in a given volume of a solvent it behaves as it would behave if it occupied the same volume in the state of a gas. This is the first feature of the modern theory of solutions. According to this theory a gram-molecule of one substance in a given volume of a given solvent ought to exert the same osmotic pressure as a gram-molecule of any other substance in the same volume of that solvent. If suitable cups could always be procured this would give a ready method for determining molecular weights.

As interesting as these deductions may have seemed, it was soon found that the law would admit of only limited application.

For example, when a gram-molecule of potassium nitrate is dissolved in a given volume of water it exerts an osmotic pressure much greater than that produced by dissolving a gram-molecule of sugar in the same volume of water. In fact only a few classes of substances obey the law. The osmotic pressure of acids, bases and salts is greater than the law accounts for. How can this be explained? Since we have found substances in solution to be like substances in a gaseous state, we should naturally inquire whether there are any phenomena exhibited by gases that would help us to explain this discrepancy in the law for solutions.

It was just after Van't Hoff had worked out the above relations that Svante Arrhenius, an eminent Swedish physicist, came forward with just such an explanation. In substance it is this: Just as ammonium chloride, for instance, when heated to a high temperature exhibits a greater pressure than is to be expected from laws for gases, so acids, bases, and salts when dissolved in water exhibit a greater osmotic pressure than is to be expected from the law for solutions; and just as the deviation from the gas laws is to be explained by the fact that the ammonium chloride is dissociated by the heat into the components ammonia and hydrochloric acid, so the deviation from the law for solutions is to be explained by the assumption that when acids, bases, and salts are dissolved in water they, too, are dissociated into two or more components called ions. In one case the dissociation is caused by the heat, while in the other case it is caused by the water. Furthermore, just as each of the simpler molecules into which the more complex molecule of ammonium chloride is dissociated exerts the same pressure as the more complex molecule itself, so each of the simpler particles callied ions exerts the same osmotic pressure as the molecule from which it is formed.

This idea of Arrhenius that many substances are dissociated when in solution was not original with him, for it had been suggested several years earlier to account for the fact that even a weak electric current can pass through water containing some acid or salt in solution. But the suggestión was valuable because it was accompanied with an explanation of a way for the determination of the degree of dissociation. To enter into a descrip-

tion of this method is beyond the scope of this paper; suffice it to say that the degree of dissociation for any given dilution is obtained by dividing the conductivity at that dilution by the conductivity at infinite dilution. By infinite dilution is meant the dilution at which the conductivity ceases to increase. During all such investigations care must be taken to keep the solutions at a constant temperature.

The degree of dissociation can also be determined by noting the rise in the boiling point or the lowering of the freezing point produced by dissolving a weighed quantity of the substance in a given weight of the solvent.

Reviewing what we have said, then, we see that there are two central ideas connected with the modern theory of solutions: the idea of the identity of osmotic pressure with gas pressure and the idea of electrolytic dissociation. Many attempts have been made to study osmotic pressure more thoroughly, but heretofore an insurmountable difficulty has presented itself in the preparation of suitable cells. However, an investigation is now being carried on in one of our universities which will doubtless lead to their successful preparation by an electrolytic method. In a few years we may hope to have a more thorough knowledge of this subject.

Since a further study of osmotic pressure proved practically impossible, physical chemists directed their attention to the subject of electrolytic dissociation and it is in this field that such a vast amount of material has been accumulated. I can mention only some of the most important points that seem to be established.

In the first place it is generally agreed that a great deal of importance attaches to these things that we call ions. In fact all chemical reactions seem to be reactions between ions. Furthermore, a compound can be ionized by an extremely small quantity of the solvent, generally water. To take a few examples: Perfectly dry ammonia gas does not combine with perfectly dry hydrochloric acid gas, but if a very small quantity of water be present reaction proceeds rapidly until it is complete. This is explained by saying that in the first case we have only molecules and there is no reaction, while in the presence of even a minute quantity of water we have some of the molecules of each substance dissociated

into ions, reaction then takes place, more ions are formed, followed by more reaction and so on until the process is complete. Again, no reaction takes place when dry sodium is dropped into perfectly anhydrous sulphuric acid. Dry hydrochloric acid may be passed over sodium carbonate without decomposing it, brought in contact with litmus without affecting it, or conducted into a solution of silver nitrate in anhydrous ether without precipitating the silver. What would happen in either case if even a small quantity of water were present even a tyro in chemistry doesn't have to be told. Numerous other examples might be given.

The question might very naturally arise, is water the only solvent capable of dissociating compounds? Many investigations have been made to settle this question and from them it has been found that many other solvents have this dissociating power. Liquid ammonia, liquid hydrocyanic acid, liquid sulphur dioxide, the chlorides of sulphur, phosphorus oxychloride, arsenic trichloride and trichloride of antimony dissociate electrolytes. Many organic compounds likewise possess this property, for example the alcohols, acids, and ketones, their power of dissociation diminishing with rise in molecular weight. It is singular that while phosphorous oxychloride possesses this property, phosphorus trichloride does not; antimony trichloride does while the pentachloride does not. The hydrocarbons dissociate electrolytes to only a slight extent.

Some attempts have been made to connect this property of a solvent with some of its other physical properties. For instance, results obtained thus far seem to indicate that there is a close relationship between the ionizing power of a solvent and its dielectric constant, or, as it is better known, its specific inductive capacity, that is its capacity to induce static electricity in one conductor when placed between it and some other conductor which is already charged.

Then again, there seems to be a definite relation between the power of the molecules of a solvent to associate with one another forming more complex molecules and the power of that solvent to ionize substances dissolved in it. For example, water is a very strong ionizing agent, and certain investigations recently made on the surface energy of water give strong grounds for regarding

water as $(H_2O)_4$ instead of simply H_2O. In other words, in water under ordinary conditions we have apparently an association of four molecules to make one, and the power of water to ionize substances seems to depend upon this association of its molecules.

Some one might see some relation between this dissociating power and still some other physical property. Perhaps other relationships may be found. Probably the truth is it is not entirely dependent upon any one physical property but is in some way connected with all, or, as someone else has put it, perhaps all the properties of a substance are a function of the energy relations of that substance, and ionizing power is simply one of these properties.

In conclusion let me say that our interest in the modern theory of solutions should not diminish when we learn that it applies only to dilute solutions. It must be remembered that we attach a great deal of importance to the ordinary gas laws; but they, too, fail to apply to highly concentrated gases, that is, to gases when they are near the conditions of liquefaction. The theory of electrolytic dissociation has been very fruitful in its suggestions It has given us an entirely new point of view from which to consider chemical reactions; it enables us to interpret much more clearly the phenemena of electrolysis, and has practically solved the question as to the seat of the electromotive force in primary cells; it has also proved of value to the physiological chemist both in the interpretations of facts already known and in the suggestion of experiments that have led to new discoveries. No doubt the theory has been overridden, but doubtless this is true of every theory upon its first appearance. Let us follow its further development and in time we shall learn to know that which is false from that which is true about all these phenomena.

THE STUDY OF HEAT IN A ONE-YEAR COURSE IN PHYSICS.

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The conviction is growing among teachers of the subject that the difficulty of physics to students in secondary schools is due rather to the common attempt to cover too much ground in the time available than to any real difficulties inherent in the subject.

A year and a half at least is necessary for a thorough course in elementary physics if no part of the subject is to be slighted. The courses in almost all of our schools, however, allow only one year's work in physics.

The teacher, therefore, encounters a serious problem at the outset of his campaign. He must decide whether to make a forced march around the entire circle, attacking everything he meets, never pausing to contemplate the condition of his ranks nor to care for his wounded or dying, or, on the other hand, to select a more limited field of action, choosing certain points of attack because of their peculiar advantages, perhaps of vulnerability, perhaps of strategic importance.

If the latter course be chosen, as we hold it should be, the selection of the points of attack must be made at once.

By common consent, the fundamental subjects of mechanics of solids and fluids will be given the precedence over sound, light, heat and electricity, both in the order of presentation and in the amount of time alloted to them. Almost, if not quite, a half year is necessary to a proper development of mechanics if an ample amount of laboratory work is given.

But when the choice of other subjects, which shall receive especial emphasis, is discussed, we shall probably find a great diversity of opinion among teachers. Perhaps most teachers will agree that sound and light should follow mechanics, as they offer an admirable field for the application of many of the principles of mechanics; but that no great length of time should be given to them in a one year's course. A series of talks, illustrated with numerous lecture-table experiments, will make these subjects in-

telligible and interesting and yet allow the anxious teacher, hard pressed for time, to cover this portion of the year's work in a few weeks.

Heat and electricity now remain, but certainly not enough time remains for the proper development of both.

The decision as to which shall receive the more attention will depend largely upon the ends sought by the teacher. If the utilitarian value of subject matter appeals strongly to him, he will choose electricity, for "this is the age of electricity," and the information gained is "practical." If, however, the development of mental power is his greatest consideration, he may well turn to the subject of heat.

In this decision he may be influenced to some extent by the order of sequence of sciences in the school course. The best opinion is rapidly coming to agree that physics should precede chemistry in the secondary school. Under this arrangement the careful study of heat will be of especial value as a preparation for chemistry. The chemistry student will need clear notions of temperatures, the effect of heat on gas volumes, specific heat, heat of fusion and of vaporization and other energy changes involving heat. If these matters have been neglected or hurried over in physics, much valuable time will of necessity be taken for them from that allotted to chemistry. It is true that electricity and light are more or less closely related to chemistry and are needed there, but they come in touch with general chemistry less frequently and in a less fundamental way than heat.

But apart from the value of a knowledge of heat as a tool in further scientific study, a number of the strongest reasons exist for giving the subject especial attention in the one year's physics course.

1. The whole conception of the conservation and transformation of energy was first inspired by some simple experiments in heat. And to this day there is no other road to correct notions of energy changes which is so direct and so easily traveled as that blazed out by the pioneers Rumford and Davy, Mayer and Joule.

2. The subject of heat furnishes a number of valuable concrete problems suitable for individual laboratory work. No other

problems ordinarily given in elementary laboratory courses require more consistent carefulness in the worker than those in calorimetry. Numerous sources of error must be guarded against. Vigorous thinking must actually occur. Such problems, successfully accomplished, bring to the student a sense of power that can not fail to stimulate and inspire him.

3. The facts and principles of heat are peculiarly fitted for use in numerous problems which involve reasoning of no mean order, and thus give unsurpassed material for the development of clear and logical thinking.

Should especial attention and time be given to heat, for the reasons mentioned or others, several weeks' work in electricity will still be possible. While a half year should certainly be given to this broad subject, if the time were available, nevertheless six or eight weeks' work, if judiciously expended, will be of great value to the student. Opinions will vary among teachers as to whether this time should be given to theoretical electricity principally or to the study of electrical devices, and as to the character of the accompanying laboratory work—even, perhaps, as to whether much or any laboratory work should be attempted.

It is believed by the writer that a year's course in physics, such as has been outlined, while not exhaustive, is rational, and that the material offered can be digested and assimilated by the serious student.

It remains to discuss somewhat briefly what the course in heat should be. In this matter, as in the former concerning the time given to heat in the one year's physics course, the writer makes no claims of either originality or authority. He simply wishes to suggest a natural method of presenting the subject and to emphasize certain points which seem to him of especial importance.

The subject of heat may, from the teacher's standpoint, be divided into two parts, the first consisting of those topics especially fitted for lectures and illustrative experiments, and the second those especially adapted to laboratory work.

In the first class fall such topics as the nature and sources of heat and the transmission of heat. Scores of simple experiments

are available for the demonstration of the facts that lead to the universal acceptance of the modern theory of heat; for instance, the classical experiment of Tyndall, in which a brass tube of water is set to boiling by continued friction. This portion of heat is well developed in nearly all of our text books, and the vigorous teacher will make it intensely real and interesting to his students.

In the second class fall the quantitative portions of the subject, including coefficients of expansion and calorimetry. It is with this part of the subject that this paper is intended to deal especially. And as the time will not permit of covering the field completely, the remainder of the discussion will be on the general subject of the teaching of calorimetry.

At the outset it is imperative that the student gain clear conceptions of the terms and quantities constantly used. Definitions must be carefully worked out for the terms thermal unit, calorie, thermal capacity, specific heat, heat of fusion and heat of vaporization. It is not sufficient that these definitions be memorized from a book. The definitions given in the text should be scrutinized and criticised.

One of the best text books in physics, one that is used largely in this state, defines the thermal capacity of a body as "the number of calories required to raise the temperature of the body through one degree centigrade." This excellent definition, showing the thermal capacity of any body to be a concrete number expressed in calories, is followed by the statement that the thermal capacity of a unit mass of a substance is its *specific heat.* As an example, the specific heat of mercury is given as .033, an abstract number. Here is a distinction with a difference. It is true that the specific heat of a substance is numerically equal to the thermal capacity of a unit mass of it. But even this modified statement fails to define the term specific heat. Specific heat bears the same relation to the thermal capacity of a unit of mass that specific gravity bears to density. The student should see that specific heat is always an abstract number, because it is the ratio of the thermal capacity of a substance to the thermal capacity of an equal mass of some standard substance.

This point is not merely an academic one, but is vital to the

mental process involved in solving for the specific heat of any substance, whether the data used be obtained in the laboratory or from a list of problems.

With these notions of heat units and quantities clearly defined in the student's mind, he is ready to apply them concretely in his laboratory work. In the instance already mentioned of solving for specific heat, he knows at once that he need only find the thermal capacity of the given body of known mass and compare his result with the thermal capacity of an equal mass of water. His real problem, then, will amount to mastering a method (say that of "mixtures") for determining the thermal capacity of his sample. He will have no feeling of vagueness about the object of his work to disconcert him, and every step in the problem will be clear and full of meaning to him.

The same natural method, based on clear conceptions of the quantities used, supplemented with a constant demand on the part of the instructor for the use of plain common sense in working out each step, makes the determinations of the heat of fusion and the heat of vaporization of water or other substances a real delight to the student.

The determination in the laboratory of the specific heats of two substances is strongly recommended. The first substance used should be of the same material as the calorimeter employed. While the mental process used is slightly different from that in which the thermal capacity of the calorimeter is known in the beginning, it is not more difficult and gives incidentally the data for the thermal capacity or "water equivalent" of the calorimeter which will be used in the determination of the second substance, and also for finding the values of the heat of fusion and the heat of vaporization of water.

These four experiments are perhaps sufficient for the laboratory work in calorimetry, but they must be repeated, if necessary, until good results are obtained.

They should be supplemented, however, by the solving of numerous problems requiring the application of the principles and knowledge already obtained. These problems should be somewhat varied in form, giving some opportunity for the use of orig-

inality and ingenuity on the part of the student, yet not too difficult and complicated.

The writer has found that much interest is aroused by three problems, in which steam is brought into contact with ice, the amount of steam and ice used changing in each problem, so that in one some ice remains, in another there is an excess of steam, while in the third both steam and ice disappear. In each case the amount and temperature of the resulting substance or substances is to be determined. Such work is of great value to the student, as it requires close thinking and is a fine mental exercise. It also affords the teacher an excellent means of determining the thoroughness and efficiency of the student, if the problems are given and worked out in the class room.

In the study of heat, as in all other portions of physics, the development and use of the formula should be the final step. The usefulness of the formula as an abbreviated, concise statement of the relation of the quantities involved in any problem is unquestioned. But dangers arise from its being introduced before the student has grasped the significance of the relations it expresses.

It is unfortunate, indeed, if the student solves his problems by simply substituting values in a long formula and then reducing his expression to its simplest form. This is a good enough practice in the algebraic process of substitution, but it involves no use of the reasoning powers, and, if repeated a hundred times, gives no stronger grasp of the principles involved in the operation. In this case the partial results have no significance to the student, who wonders vaguely what the denomination of each result may be, and is much relieved to find that the expression, when solved, brings him the right answer.

If, however, as the result of real mental labor, the significance of the quantities used and of their relations to one another is first comprehended, the formulation of an abbreviated expression of those relations is a simple matter.

WHAT SHALL THE PREPARATORY SCHOOL GIVE IN THE WAY OF CHEMICAL TRAINING?*

BY WILLIAM HOSKINS.

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My lack of experience in either the science or art of teaching prompts me to approach this subject with much circumspection and diffidence, but when we note the rapid change which has taken place in educational methods within recent times, the desirability of sober discussion of all matters pertaining to a course of study or the objects of a course of study by those interested (and who should not be?) must be apparent. I am therefore glad to have an opportunity to say even this much to a gathering of this kind.

Any scheme, any curriculum, any detail, is of necessity an experiment. In our laboratory, if an experiment fails, it may be repeated, perhaps with a change of apparatus, or a change of method; but in a school, where every recitation, every demonstration, every act, constitutes a part of the alembic which molds a generation, what care should we use that in our instruction we employ the best our pedagogy suggests; how great the responsibility then of him who says *this* is the way: and therefore, as intimated a moment ago, I do not feel prepared to indicate the particular line of work which should be included in the chemical curriculum of the high school, possibly, however, I may be allowed to suggest what, it seems to me, are desirable results, leaving you to plan the proper course of study to attain them.

Chemistry is a very new and rapidly developing science, depending largely for its progress upon the correctness of the conceptions which have been advanced from time to time and which have been used as hypotheses to explain the phenomena observed. The atomic theory is, of course, the foremost of these, and so, if the student studies chemistry at all, he should have some notion of this hypothesis, but it must be remembered that any mode of thought established in youth is difficult to overcome, and the reception of new ideas, contrary to early teaching, less likely in proportion to the positiveness of the early training.

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*Read at the meeting of the Chemistry Section of the Central Association of Science and Mathematics Teachers, April 10, 1903.

Let us be careful that we do not produce confirmed atomists, ionists, etc.; such are as unfortunate as individuals in any walk of life who can see through but one pair of spectacles. The course in chemistry should assist in the development of broad-minded, receptive and rational men and women, and so, while the student must have been given some understanding of the theories upon which the science is built—as much as is necessary to have him understand and properly classify the facts he learns—he must realize, too, that these theories are but expedients and may change as our knowledge increases.

As to the facts he acquires, it would be best that his work should be, as much as possible, with forms of matter with which he is apt to come in contact in the ordinary and not the unusual walks of life. It is important that a high school graduate know the properties and uses of the common metals thoroughly, and something of their ores and metallurgy, even if he has not learned that helium exists in the sun. He should know something of the chemistry and manufacture of building material, and should know about the chief chemical industries, their magnitude, their possibilities and importance and their general interdependence. This means, of course, an instructor who keeps informed on the technical side of the subject as well as the theoretical and who is able to point out the relation which his laboratory experiments bears to the world we live in.

Ten years ago the Committee of Ten of the National Educational Association called attention to the fact that more time is required of efficient science teachers than of those in other branches. This is no doubt true, and in order to be successful he must keep posted; and he is particularly valuable if, in addition to other requisite qualities, he knows something of the practical applications of his science at first hand. It would do no harm if he subscribed for a trade journal or two.

To return to the student. It is a mistake, I think, to attempt to make analysts out of secondary pupils, even to a small degree—as much a mistake as to attempt to turn out mechanical engineers from a manual training department. To be sure, a secondary school graduate may be useful in an analytical laboratory, or about a chemical works. So, too, might the graduate who had studied biology in

the high school make an intelligent assistant to a surgeon; but he would always be as far from being a surgeon in the latter case as he would be from becoming a chemist in the former. He has a beginning, it is true, and what won't yield to the determined, persistent effort of an intelligent ambition? But education is a time saver and systematizer, if it is good for anything, and so we have our technical schools for chemists, electrical engineers, physicians, etc.

There is no place worth having in any chemical laboratory that a graduate from a secondary school can fill. At best he will have a *mere job,* for which one with a primary schooling may readily be trained.

The aim of a secondary school course in chemistry should be mainly to form a part of a curriculum which has for its object the training of people to see straight and think clearly, and not to make chemists. Incidentally it should give the student the power to discriminate between the possible and impossible and the capacity to separate the possible into the probable and improbable, so that he will be able to place at its true value a scheme to make gold from antimony or refine sugar by electricity.

If his science has taught him something of the cause of the prismatic arch after a summer shower, he will not be so apt to seek for the elusive pot of gold at the base of a rainbow. Of course the chemical course must take cognizance of the demands of the college and university and must so shape the work that, while it has the greatest educational value, no time will have been lost by those intending to pursue the study as a specialty.

In conclusion, I urge the teacher to point out the wonderful possibilities and future of chemistry, how the science is knit into every walk of life, manufacture, commerce and art, and if the student has a special bent, show him without discouragement the necessity for further training, this being the only way to acquire the power to recognize opportunity.

Fire him with an ambition for something more than a mere job, and show him that he can not bore a large hole unless he provides himself with a big augur.

FIELD WORK IN PHYSIOGRAPHY.

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It is my purpose in this paper to treat in a very restricted way a subject full of opportunities.

Until an orderly plan of field work is evolved from the present chaos of ideas, and a schedule, sufficiently broad to be adapted to the varying conditions and environments of secondary schools throughout the country is agreed upon, it will be well for the teacher to study out for himself what the possibilities of his region best offer, then to so plan his work as to bring out the best there is in it, and to correlate it in scientific harmony with the efforts of his co-workers.

The tendency is to place the elementary study of earth science early in the high school course. This plan has many good reasons for its maintenance, but personally, I advocate having some of the work late in the course, or having an advanced course offered as an elective in the fourth year. It is with fourth year pupils that I have been privileged to work, and I doubt if my plan would, unmodified, be practicable with younger pupils.

The possibilities of a region, then, is the keynote of the plan which, if followed in specialties from term to term, will in a few years result in the accumulation of much valuable data, which must be carefully preserved, and may finally be arranged into a syllabus of information from which maps of the topography, areal and economic geology, water supply, and general physiographic features of the district may be constructed by the careful student who has obtained a broad grasp of the subject. Such work, if properly begun and systematically, even though slowly, advanced by the persevering teacher, will in time bring forth results that will bear the stamp of true value when the growth of his department is reckoned with.

Recognizing that the subject of topographic map-making offers a wide diversity of interesting work in and about Sioux City, I have taken that up as a special adjunct to the year's work. The necessary equipment is not elaborate. An aneroid barometer, a

compass, a hand level, a ten-foot pole, a hundred feet of measuring tape, note books with coördinate ruling, protractors, and pencils complete the field equipment. If two sets of the first three instruments are available, two independent parties may work at once and thereby the practice be extended to all members of the class more rapidly.

The barometer should be of good grade, compensated for temperature, and capable of recording a change in elevation of five feet. Its face should have a movable rim graduated in feet so that the readings may be made directly and the instrument set at a known elevation whenever desirable. It should not be much larger than a watch, so as to be conveniently carried in the vest pocket. Such an aneroid costs about $20 and is also quite essential to a physics laboratory. An excellent form of compass is the "Geologist's," made of aluminum, with a base four inches square, the edges of which are bevelled and graduated, two of them for a tangent scale and the other two with scales of eighths and tenths of an inch. The base is provided with spirit levels and folding sights, one of which carried a reflector. There is also a screw and lever for setting and releasing the needle, and the graduated circle is movable so as to be adjusted for magnetic variation. The face is also provided with a clinometer with separate graduated semicircle. The cost is about $20. The Abney form of hand level, with a clinometer for giving angles of elevation is a very satisfactory instrument. Its retail cost is about $13.50.

A map made with the above equipment accompanies this article. (Fig. 1.)

In order that the pupils may at the outset become familiar with the plan and purpose of a topographic map the maps of Folios 1, 2 and 3 of the Topographic Atlas of the U. S. (Physiographic Types) are studied, and for purposes of class discussion I have prepared lantern slides of all the maps in the series. Profiles of roads and streams, cross sections, generalized topography of portions of each map, represented in color, and other exercises of a similar nature based on these maps are required of the pupils.

The field work must necessarily begin early in the fall term, perhaps before each pupil understands the full meaning of the

work, and is carried on contemporaneously with the study. Exercises in making profiles up and down several streets or suburban roads come first. (These would hardly be profitable in a flat country.) I make it a point to conduct a *small* part—say of four or five of the aptest boys in the class at first—and acquaint them with the methods of work, subsequently giving each one of them charge of a party or of a division of the work.

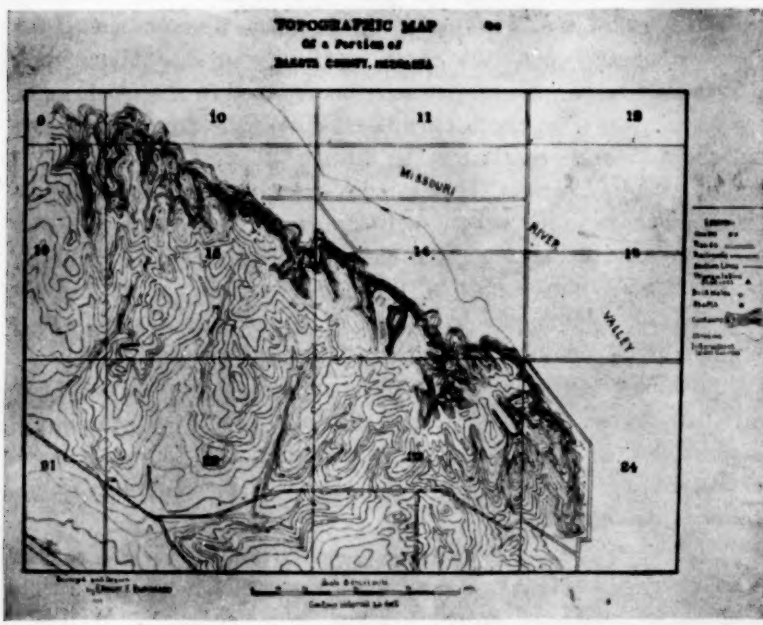

Fig. 1.

This work is then continued by various assignments so made that the work of each party is checked up by the work of others, and is extended to profiles and cross-sections of all the surface features so that little detail is omitted. When pupils begin such work independently, if in the city, the instructor can have at hand as a check on their results the city engineer's grades for street intersections. One field exercise a week for each pupil, occupy-

ing three to five hours, during six weeks, planned as outlined, will be found to be ample time for a large quantity of work, and will furnish material for indoor work for the remainder of the term.

It is not the intention to have each pupil perform all parts of the work, but it is the intention to have him be able to interpret the work of every other pupil so that if called upon he may continue a piece of work or explain its application. After all the important elevations in the desired area have been obtained, and the location and direction of the drainage features noted, the same are placed upon base maps. (County or city maps upon a sufficiently large scale may usually be obtained so that each pupil may have a copy, or else a tracing may be made from which any number of positive prints may be taken.) Then the sketching of the topography begins. This is conveniently done in small sections on a large scale, on base maps drawn on the coördinate paper in the note books, showing the observed elevations at the proper stations. Some pupils will be found not to have the desired art of expressing topography by means of contour lines, and it will be difficult for such to acquire it in the limited time, but this work will find its devotees as well as the more monotonous parts of the work have done. Finally, if any two or more of the completed areas adjoin, they can be given to certain pupils to join up and reduce, letting the pupils go into the field to inspect doubtful points if necessary.

If such a plan as this is followed, it should not be a matter of discouragement if only a few blocks in the vicinity of the school building are mapped in one season, or a portion of a public park, or the vicinity of a water supply reservoir, provided the start is made and what is done is done with painstaking.

An especially valuable subject for topographic work is a region in which there are frequent outcroppings or exposures of rock. When the study is begun of the geology, nothing is of greater value in connection with the geological mapping than a good topographic map having a small contour interval.

Not having stood the test of extended use, the plan may be found to have certain disadvantages, but essentially, in its incep-

tion, it builds for the future—a long way in the future—and every teacher will recognize that at least it is destined to relieve him of the monotony of an oft repeated course, and will incidentally afford him a chance to shape some practical, original work.

A NEW AND CHEAP FORM OF AUXANOMETER.

BY F. E. LLOYD.

Department of Biology, Teachers' College, Columbia University, N. Y.

It is very much more interesting and instructive, in elementary courses in botany, to observe periodicity of growth in plants than merely to demonstrate, by means of a lever, what every one knows already, namely, that plants grow. It is sounder pedagogically to do such experiments quantitatively, since, when so performed, they mean very much more in training. It is for this reason that attempts have been made to construct a cheap form of auxanometer by attaching a recording cylinder to the minute-hand spindle of an ordinary clock. It is obvious, however, that the centering of a cylinder, and its vertical adjustment without lateral movement, are by no means easy of accomplishment. A cylinder is very likely to revolve irregularly unless made with very great care, a process which involves turning and centering on a lathe, and skilful mechanical adjustment to the clock. I have to confess to failure in this direction, except after a too great expenditure of time and labor. Happily, however, this experience has led me to devise a very cheap and accurate mechanism which accomplishes the end desired, and this at a very small cost of money, time or skill. This is done by substituting for a revolving cylinder, a lever, which is jogged once an hour by an arm moved by the minute-spindle of a seventy-five cent clock.

As will be seen by the illustration the lever bearing the record is fixed on a horizontal axis, and stands vertically upward, held against a block by means of a thread, reeved through a wire pulley, drawn sufficiently taut by means of an attached weight. This weight must be heavy enough to draw back the record lever to the block when it has been displaced from the vertical, say from

0.5 to 1.5 cm., according to the length of the lever and of the record. The arrangement of thread and weight was chosen because, with a little adjustment, the lever may thereby be pulled back quietly and quickly without shock or vibration, after it has been moved by the minute-spindle arm. To set up such an apparatus one may proceed as follows: Take a box, a wooden packing or mailing-box of suitable size, say approximately a cube 15-20 cm. on a side, fill it with gravel and nail it up. This makes a good, solid stand. Its solidity is enhanced by gluing on the under side as feet, three bits of thin cork. Upon the top of this

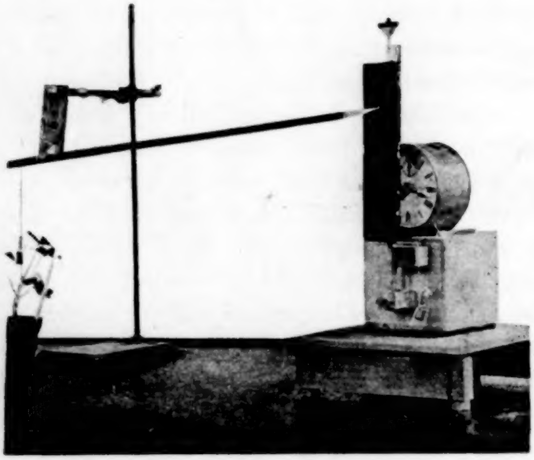

Fig. 1.

stand is affixed a cheap clock from which the glass face has been removed. Its minute-hand must be suitably bent in an L, or in its place an L-shaped arm affixed to the spindle, so that during its rotation it will move against a shoulder or pin on the record lever. This lever is a wooden arm on an axis attached to the side of the stand below the clock. A little care must be given to adjusting the axis—a wire nail serves very well—so as to avoid any lateral shake. The shoulder or pin upon which the minute-spindle arm plays should be arranged so that the record lever will be moved but a little distance, and then be released. It will

then be drawn quickly back to its vertical resting position against the wooden block. It is plain that the recording point of the auxanometric lever itself, which is attached to a growing plant, will make a horizontal mark, if allowed to drag across a sheet fixed to the lever arm, or exactly speaking, an arc of a large circle. Since the end of the lever, attached to the plant, is constantly

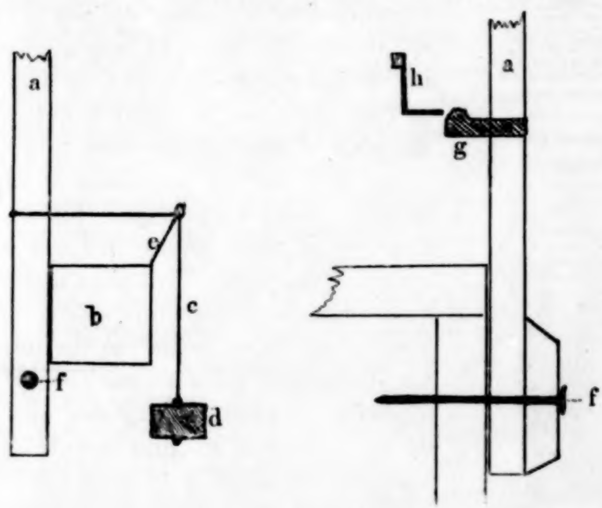

FIG. 2. Sketch to show details of lever mechanism. *a,* lever, carrying record; *b,* wooden block; *c,* thread, to which is attached weight, *d,* and which moves through bent wire pulley *e; f,* pivot; *g,* shoulder on which the arm attached to minute-hand spindle, *h,* impinges; if the latter is bent once more at right angles, the shoulder, *g,* need be but a simple pin. The arm, *h,* is displaced to one side to make the drawing clearer.

falling as the plant grows, it is obvious that the distance between these marks, which will be made at hourly intervals, will show a record of the growth, amplified of course, in the ratio of the lever arms. The chief difficulty, and this is but a slight one, is in getting the planes of the two levers sufficiently parallel so that the recording point will work freely and at the same time not swing away from the surface on which the record is to be made. When this trifling obstacle has been overcome, one has a piece of apparatus which will give a beautifully exact and clear record of hour intervals of growth. It will readily be seen that half-hour

intervals may be obtained by having a double arm or by placing two shoulders or pins on the record lever in the proper positions. Such brief intervals are, however, hardly useful except in special cases.

The auxanometric lever should work easily and smoothly and truly in a vertical plane. This may be accomplished in a manner devised by Professor Herbert M. Richards, who kindly allows me to incorporate the idea in this paper. A U-shaped piece of metal is cut out, and the ends of the legs are bent to a J-form. These serve as beds for pieces of capillary, or very heavy-walled, glass tubing which function as "hole jewels" for the pivot of the recording lever. This pivot may be made of a thinnish needle, preferably a long one. Placing the "hole jewels" on the pivot, they are bedded into the J-shaped arms by means of shellac or, better, sealing-wax, and adjusted so as to give as little end-shake to the lever as will allow it to work freely. The lever and its support are then a simple piece of apparatus which may be held in place by means of a clamp. The clamp may be easily improvised, a gravel-filled box or bottle serving as a foot, or a retort stand may be used.

FIG. 3. Record of growth of *Vicia Faba* seedling. The dots opposite the marks indicate six-hour intervals, beginning at 6 p. m., May 14, 1903. The decrease and irregularity in growth after the first twenty-four hours was due to unfavorable conditions.

The recording pen is very satisfactory if made of sheet celluloid, which may be appropriately bent so as to scratch lightly on smoked paper or mica, attached to the lever actuated by the arm on the clock. Mica is especially good because it does not warp if carefully smoked and may be used in making sun-prints. The record reproduced in the accompanying figure was made in such a way. Some pieces of bent tin serve to make a holder for the recording surface or it may be attached simply by thumb tacks.

A PLEA FOR EXPERIMENTAL WORK BY THE STUDENT IN TEACHING A FIRST COURSE IN PHYSICS.

FIRST PAPER.

BY W. F. MONCRIEF,

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Prescription of the details of the method to be used in presenting any subject is certainly of doubtful value. It ties the hands, clogs the brain, dwarfs the enthusiasm and cancels the personality of the teacher. This view is most strongly emphasized in the "about face" of pedagogy within the last ten years. Fifteen or twenty years ago pedagogy, so-called, consisted mainly in detailing to prospective teachers just how they should present each branch, each subject, each topic and each sub-topic—giving specific directions as to the method of approach, lesson plan, etc., etc., even the literal following of the "Herbartian Scheme" being insisted on in extreme cases. Now the foremost pedagogy not only repudiates all this as a wanton waste of time and energy, but denounces it as a source of positive and often fatal injury to effective teaching, since it tends to convert the living teacher into a lifeless machine. All that enlightened pedagogy now attempts at this point is to make the teacher thoroughly conscious of the nature, historical development, social implications, relations and bearings, and of the educational functions of the subject matter with which he proposes to deal, holding that such saturation will enable him to see that the essential features of his method inhere in an adequate appreciation of what he is dealing with and what he proposes to do with it, and that his own personality, thus enthused, may be trusted to evolve the details of his method. But while modern pedagogy condemns in unmeasured terms the quackery or dosing out to would be teachers as the elixir of method, the "bread pills" of petty devices, tricks and schemes, sugar-coated and put up in insoluble water-tight capsules to be swallowed without question at stated times, according to prescribed directions and in an invariable order, it also recognizes the necessity for a method of teaching any given subject, determined on the one hand by the subject matter and the personality of the teacher, and on

the other by the kind of students taught and the conditions under which the work must be done. Although the writer should wish to reserve the right to dissent from some of the demands of current pedagogy yet he is obliged to accept, in the main, its interpretation of the conditions which should control the evolution of the teacher's method and the restrictions which it is wise to put upon the freedom of its execution. Hence no specific directions, good alike for all, detailing how to teach this, that, or the other topic, will be presented here. The details of how his own classes actually work will not be discussed. The only concern here is about the spirit of the general method necessitated by the nature of physical inquiry, its function in an educational scheme, and the needs of the student who approaches the subject for the first time. No attempt will be made to show *why* the method of experimental work by the student *is* the one demanded by the above conditions, though this would not be hard to do. Nor will the ground of the fact that this method is best both for the student who expects to teach physics and for the one who does not, be formally discussed, though it may come out incidentally in dealing with the advantages of the method.

Experimental work by the student implies that he shall himself do, under the general supervision and direction of the teacher, all the investigation necessary for the derivation of every physical law and principle with which he is brought in contact. Not that he should attempt to work out book values, or to secure those highly accurate results which come from much experimentation by expert manipulators equipped with the most refined apparatus and working under the most advantageous conditions. Nothing of that sort is meant. Such work would be equally impossible and undesirable in a first view of physics. But what is meant is that the student shall do for himself in a rough way with such apparatus as he has or can devise *the very same kind* of investigation that the scientist does in establishing these laws and principles and that he shall, due allowance being made for known sources of error, obtain reasonable approximations to accepted results. What shall constitute a "reasonable approximation" would have to be determined by the teacher and would obviously be controlled by the

nature of the problem, the kind of apparatus available, the time at command and the skill of the student. Experience shows that at this point liberality is the better part of discretion. It is hardly wise to discourage honest and independent work by too rigid exactions. Results that furnish evidence enough to create a strong suspicion of the presence of a law or principle being often "sufficient approximation," provided the student sees clearly *why* his error is large and that his method would, with better appliances and more favorable conditions, give better results. About the only work that it seems safe always to reject is that which finds exact results (implying mere accident, or unwarranted manipulation of data) and that which shows wanton carelessness. But the main point for the teacher to keep constantly in mind is that his student is an investigator, seeking by means of his own efforts to find out what is truth—not a mere imitator or verifier of the results obtained by others. He must therefore have before him a clear-cut open question with regard to the unbiased determination of which he seeks evidence—a well defined problem whose impartial solution he is attempting by, what is for him, first hand investigation. Hence in his experimentations, observations, and manipulations of data he must be free from prejudice, thoroughly honest and absolutely disinterested as to the outcome—caring not a whit whether the evidence should point this way or that, necessitate one conclusion or another. The conclusions reached must be deductions from the evidence observed, not statements memorized from a text or learned from a teacher. The laws and principles derived must be inferences warranted by the conclusions from the evidence.

This work intelligently done, the student has little to memorize. He knows the truths and principles with which he deals and every inch of the ground on which they stand. He has worked them out and they are his. He can, therefore, recognize and appreciate their operation in the world about him and apply them in the practical affairs of every day life. The advantages of this method over the text-book-recitation method or the lecture-demonstration method (the teacher "performing" the experiments) are in the main briefly as follows:

1. It develops and trains the powers of observation. Few

know how to observe. To the great majority all features of a situation are equally valuable. They can not distinguish between the essential and the accidental, the relevant and the irrelevant, the legitimate and the illegitimate. First hand contact with concrete data where the value of the result depends largely on the character of the observations will materially improve this.

2. It trains in manipulation—makes the muscle sensitive and the hand dextrous.

3. It develops "common sense" and sound judgment. The student must use his mother-wit in order to grasp concrete situations and adapt means to ends, and his judgment in attacking problems and testing approximations.

4. It enables the student to think on his feet. He must reflect on the situation before him that he may explain the phenomena which appear and draw conclusions from the evidence at hand.

5. It teaches him the limits of legitimate inference from observed facts. How wild are the inferences drawn by the untrained mind from a given body of facts! And how much of the world's dispute and wrangle is due to illegitimate inference!

6. It cultivates and strengthens the "scientific imagination." It is imagination that must make the leap from fact to theory, from conclusion to inference, from special case to general law. Imagination must complete the picture the barest outline of which is given in his observations.

7. It gives meaning and reality to physical truth. He has derived it out of his own experiences and therefore it is a part of his conscious life and he can use it.

8. It makes him more self-reliant, resourceful and initiative. His habit is to depend on himself and he must constantly invent the means of reaching his desired ends.

9. It makes him more critical and more conservative. He can not afford to take things for granted, accept superstition and hear-say. He must know the ground on which he stands and therefore must examine it. But he is always open to conviction on approved evidence.

10. It gives him the scientific attitude of mind—that of first hand investigation in a disinterested search for truth.

11. It increases his respect for authority but diminishes his servile subjection to it.

12. It acquaints him with the scientific method of investigation and enables him to read scientific literature with appreciation.

13. It enables him to draw a sharp and appreciative line between scientific fact and scientific theory. How valuable this is! Nine-tenths of the imaginary discrepancy between science and religion is due to lack of ability to draw this distinction clearly.

14. It gives him an indispensable point of view from which to evaluate scientific theories, laws and principles. The world is filled with misapprehension as to the significance and validity of these things. It takes many of them for final statements of absolute, fixed truth; while as a matter of fact, such is almost never the true case. This needs to be rectified.

15. It strengthens moral conviction broadens faith and secures ethical and religious doctrines. It accomplishes this by convincing the student beyond question, that all scientific truth rests on *evidence—not proof*. That the demand of medical science (now the demand only of second-class scientists posing in the name of science) for *"proof"* in ethical and religious matters is unwarranted and unreasonable and comes with ill grace from a realm where "proof" is a total stranger. That faith* is as large and necessary an element in the scientific world as in the religious world and that, eliminating inspiration, whoever accepts the former may consistently and with equal rationality accept the latter. That, in fact, faith is the universal, necessary and sufficient basis of all phases of intelligent life and, therefore, to reject any phase of life because based on faith is the most inconsistent and irrational attitude that an intelligent being can assume.

It is confidently believed that none of these advantages can be half so well secured by any other method of teaching physics (or, for that matter, any other "natural science"), and that most of them can not be secured at all by any other method. The utmost that any other method can do is to secure the memorizing

*Faith as here used consists in accepting on evidence that which can not be proved and acting toward it as though it were true.

of a few facts, laws, and principles having little of meaning and less of practical relation to anything in actual life. At least that such was the result in the case of one who has been a student and a teacher of physics both by the text book method and by the text-book-lecture-demonstration method is beyond all question in the experience of the writer, being a fact of immediate consciousness.

In the next article objections to attempting this method, likely to be raised by teachers in high schools and colleges, will be discussed and evidence pro and con from the experience of students who have worked by this and other methods will be introduced.

THE DISSECTIBLE LEYDEN JAR.

BY WALTER P. WHITE,

Cornell University.

The treatment of the dissectible Leyden jar as given in most high school text books is a singular exception to the general accuracy of such books. Many books state that the jar, as commonly used, shows that electrification is really a strain, or other phenomenon, of the dielectric. The better books avoid any such direct statement, but they generally present the subject in such a way as to give the impression that the phenomenon and the theory are closely connected. As a matter of fact, it can easily be shown that to suppose any *special* connection is an absurdity.

On considering the theory in question we find that the essential parts of it may be expressed by saying that electrification consists of tubes of force in the dielectric and that the ends of these tubes are electric "charges." In static phenomena these tubes are never closed loops, but always end somewhere—that is, they are always accompanied by charges. If, now, we ask how the Leyden jar experiment can be thought of as illustrating this theory, the

only way, as far as the present writer can see, is this—that in taking away the metal coats of the jar we think of ourselves as removing the charges and leaving the dielectric strain behind in the glass. Of course, this conception, when definitely realized, becomes nonsense, it amounts to cutting off the ends of the tubes and leaving them without any ends. Whether it ever is held, vaguely, of course, by pupils would be hard to say. As soon as we have rejected it, however, we have surely not the least vestige of proof left. For in that case the experiment amounts merely to taking away our conductor and leaving the charge on the surface of the glass. The idea of a charge on a non-conductor is nothing new—the first experiment of a course is usually the electrification of sealing wax or rubber—so all we have is the usual two charges with intervening dielectric. Now as long as the charge is there the phenomena may as well be referred to it as to the dielectric; the tubes of force may be there or they may not, just as in any other ordinary charge.

An illustration of the modern theory which is satisfactory is easily obtained by following out the line of thought indicated above. It is impossible to assign dielectric strain as the cause of phenomena if there is a charge present which can account for them equally well; it is also impossible to separate the charge from the tube of force; but it is possible to separate their effects. Thus if the phenomena of charge are affected by altering the dielectric at a distance from the charges (as by putting a piece of glass between two plates of an air condenser provided with an electroscope) we have practically proved that there is something there beside the charge. The variation of condenser capacity with the distance of the plates also becomes far more intelligible when interpreted by this theory. The experiments necessary for demonstration are easier, the reasoning easier to understand, and the results at least as interesting and important as with electrostatic induction, while the whole subject is an exceedingly pretty example of scientific reasoning.

Metrology.*

OPPOSITION TO THE METRIC SYSTEM.

BY DR. WILLIAM H. SEAMAN.

At the December meeting of the American Society of Mechanical Engineers held in New York in 1902, a paper in opposition to the metric system was read by Mr. F. A. Halsey, and published in Vol. XXIV of their Transactions, together with the discussions thereon; also the report of a committee appointed to consider this subject, which gives a summary of arguments on both sides. In the preparation of Mr. Halsey's paper he received the assistance of Mr. S. S. Dale, also an opponent of the metric system, and editor of the *Textile World-Record.*

The arguments of the British system† are summarized (628) thus: 1. The change of system is a task of enormous difficulty. 2. The adoption of the M. S. involves the destruction of all mechanical standards. 3. The prosperity of foreign trade does not require the M. S. 4. The bill before Congress is a compulsory measure, so far as relates to those who do business with the government. (The bill for the governmental use of the M. S. was the cause of the discussion.) In reply, it is not denied that the transition period in which we now are will in its progress be attended with some inconveniences, which are greatly exaggerated, and which would be minimized by adopting the M. S. as rapidly as possible so as to shorten the period of transition. The advocates of the M. S. believe the benefits would ultimately greatly exceed the cost of the change. Mr. H. denies this, and that constitutes an issue between us.

The second statement is a very loose and indefinite one, as several meanings belong to the word standard. Its principal

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* Communications for the Department of Metrology should be sent to Rufus P. Williams, North Cambridge, Mass.

† In the following brief review of this paper citations are marked by page numbers in brackets, and for brevity the customary system is denoted by the letters B. S., for British system, and the Metric system by M. S.

meaning refers to the international meter and the imperial yard, fundamental standards for the two systems respectively. These would not in any way be affected. The second meaning may be the patterns or templates used in making parts of machines, which are constantly abandoned or altered to suit trade requirements, and as new ones are constantly being made they would be made to metric measures, and that is all of this feature. Finally we are told (434) that we are "tied irrevocably to the past" by our screw threads.* Well, we have four principal pasts—the Whitworth or English past, the Sellers or American past, the Swiss or watch system, and the international system. The last two are exclusively metric; the watch system is entirely universal, being used by both English and American watch makers. The international system of screw threads was prepared by a commission of German, Swiss, French and Belgian engineers, in 1898, after several years of discussion and preparation. This system is known as the international system, or I. S., and has been adopted and is in actual use in the government construction in continental Europe, the workshops of Schneider & Co., at Creuzot; the shops at Fives-Lille, etc. As this system, just started, comes into use, the Whitworth thread, hitherto employed in Europe will be abandoned. It must not be forgotten, it is not the Sellers or American system of screws that is used in Europe, it is the Whitworth or English system, and Continental Europe has never used or proposed to use the American system. The question of screw threads is not to be settled from the standpoint of any one nation alone, but for the whole world, and the American system has not now and never had the slightest chance of being universally adopted. We have one system for iron pipe, another for brass pipe, one for machinists' bolts and another for carriage bolts and none for hose couplings or hydrant fittings, etc.

The third point is the prosperity of foreign trade. On this point the United States consuls who are on the ground all say that it would be a benefit. Mr. Halsey says not. Who is likely to know most about it?

*** This paper is part of a pamphlet in which this subject is treated at greater length.**

Finally, no doubt the legislation in favor of the metric system would make it compulsory on those doing business with the government. If it did not it would not be of any value. In most cases the change will not cause any inconvenience to anybody, notably in the mint and postoffice, where it is already partially in use. The government can do many things without loss or injury that would be difficult for private individuals, and it would make the whole people familiar with the system, of which many are now ignorant.

Mr. Halsey's summary does not fully represent his paper, which is mostly a labored effort to show that old measures are still in use in metric countries (424); that the M. S. offers no advantages (445), and as an economic factor is worthless (451); that decimals are less useful than vulgar fractions (448), and that the B. S., by the industrial supremacy of the Anglo-Saxon, may be forced on the rest of the world (626). The use of old measures is chiefly an evidence of ignorance and inertia, of which we have less in this country than in Europe. Let the M. S. be taught in the schools and used in government transactions, and we shall soon have it in general use by the educated classes. The ultimate extinction of the old measures will be sure and rapid in proportion to the intelligence of the people. The M. S. has conquered its present position by displacing other measures, and it is certainly no argument against it that the displacement is not quite complete. Fifty years ago the M. S. was unknown to the masses of English-speaking people; today the literature of England and America is full of it. Of all the branches of human knowledge, physics and chemistry are most important to the working man. Every text book published on these subjects is now in part or wholly in the metric system. The work done in the laboratories is done in this system, the articles in all the journals containing the results of original research are published in this system. A decent education in the kind of knowledge most useful to the hand worker can not be got except through the metric system. Now, since no one has the boldness to say the M. S. is not adequate for all purposes for which any system of measures can be used, and since the M. S. is here to

stay, and is increasing in use among the nations, and among English-speaking nations, the best thing possible is to hasten the complete use of the M. S. and get rid of the inconveniences of a mixture as soon as possible. The statement (433) that there is no saving of time for school children is wrong: the old units have disappeared from the schoolhouse in most metric countries. The neglect of many of our school boards to see that the M. S. is taught in the grammar schools is criminal. In childhood dimensions are most easily fixed in the mind, and the neglect of the M. S. in early education throws an additional and unnecessary burden on the first years of high school or college life. It is not merely that a large amount of actual saving of time is made in the greater ease of memorizing the M. S. over the B. S., but the clearer ideas conveyed by it in the relations of matter dealt with by physical science make a knowledge of it a distinct gain in a successful practical use of knowledge. The statement (445) that the contents of a tank of water or the weight of any volume are determined by the same method in both systems is not true. Specific gravity is the ratio between the weight of a volume of water and that of the same volume of any substance—which number can never exceed 22, and for most cases is between 0.5 and 8 (wood and iron). With only this number, the weight of any body of known dimensions can be given, while in the B. S. the weight per unit, usually a cubic foot, must be learned in addition, involving usually two or three figures. This table is entirely dispensed with in the M. S. Many of the examples selected to show the advantages of the B. S. are sophistries. The sawed wood (413) is entirely metric; the 216 millimeters used (447) is as likely in actual practice to be 2.5 decimeters, and could then be calculated more easily than the $8\frac{1}{2}$ inches used; the potatoes (497) given in kilograms can be read instantly in tons if a larger unit is desired, etc. The B. S. is one of the greatest obstacles at present to the improvement of education in this country, and every child will be greatly benefited when the M. S. comes into use, no matter what trade or profession he may follow. And this is one answer to the constant demand made as to how the M. S. will benefit the textile industry. The tables accompany-

ing this article show twenty-eight different systems of marking yarn. The international system proposes to substitute one. It is no matter whether all of these systems are in use in one branch or not, they are a part of the present condition of the textile industry. The English dealers in yarns themselves propose to adopt the international system in the way recommended, these tables being published by a yarn dealer. They say the M. S. will be adopted by England, and they are quite likely to know as much about it as the editor of the *Textile Record*, or anybody in this country. Dyeing is a part of the textile industry, and dyeing is entirely dependent on chemistry, and in chemistry the M. S. is universal. The empirical dyer, who knew no chemistry, is giving place to the man trained in our technical schools, where they must learn the M. S., and in this way the M. S. is entering into and is necessary to the textile industry.

The constant and extensive use of decimals of an inch in machine construction has practically disposed of the old objection to the M. S., that a decimal ratio was not so useful as vulgar fractions; and the ready use of vulgar fractions in the laboratory with the M. S. wherever desired render puerile all this class of objections to the M. S. In the practical use of the M. S. the 1,000 factor is most employed, as 1,000 milligrams to 1 gram, 1,000 millimeters to 1 meter. Now the following fractions are readily used:

1	1000	1/5	200	1/20	50
1/2	500	1/8	125	1/25	40
1/3	333	1/10	100	1/50	20
1/4	250	1/16	62.5		

One-third fits in this table as well as in the binary, and the one-sixth and one-twelfth only are left out, against which we have the fifth, tenth, twentieth, twenty-fifth and fiftieth.

(*To be concluded in January.*)

Notes.

Teachers are requested to send in for publication items in regard to their work, how they have modified this and how they have found a better way of doing that. Such notes cannot but be of interest and value.

MISCELLANEOUS.

The Proceedings of the Department of Science of the National Educational Association's Boston convention are printed in separate form, and may be obtained at the price of ten cents from the secretary of the Association, Irwin Shepard, Winona, Minn. An abstract of these Proceedings was published in the October number of this journal.

Duplicating writing or figures is so useful in laboratory practice that I trust the following hints may be of use to some readers. I am always glad to pick up new points and hope this may lead others to give more on the same topic.

The mimeograph is probably to be had in every school. Anyone who copies well can make a drawing on the autograph paper. The typewriter paraffine paper, however, may be laid directly on the figure in a book, or one drawn on cardboard, and the drawing traced with the sharp point of a drawing pencil or a steel pen. In this way the typewritten text may be illustrated, leaving the space for the figure while making the stencil or putting in the figure first and then writing around it. The scratching in the stencil will look rough, but will come out very well in print.

Those who use the mimeograph know that different colored writing or drawings on the same page (for emphasis) are obtained by using separate stencils with different colored inks. This is somewhat simplified on the old-fashioned gelatine pad, although the results are less satisfactory and fewer copies can be made.

The gelatine pad of old is still sold in various forms and under new names. I have found that serviceable pads are made according to this formula: 25 grams of gelatine, 200 of water, and 50 of glycerine. With gelatine soft enough (made by adding water to the above) not to stick much, yet not to tear, a serviceable autograph hand stamp may be made. For this purpose gelatine is cast ½ or ¾ inch deep into a pasteboard box of the right size for the name or the lines to be printed. When the gelatine has set it may be taken from the pasteboard, and, making the copy with hectograph ink or copying ink (where only a few copies are wanted) and impressing it on the gelatine, it is handled like a thick blotter, applying and removing from the surface to be printed with a rolling motion. In this

way I have appended date and autographic signature to students' certificates at the rate of thirty per minute. By casting the gelatine into a frame of tin fastened to a handle a more serviceable stamp is made.

Whenever I forget to insert a carbon paper while writing a letter of which I wish to keep a copy, the desired copy is quickly made on a gelatine pad. A further illustration is that this description, I find, is written on a sheet that has another subject written on the other side. I can not send both to the printer, but I can make a copy of this side.

L. M.

PHYSICS.

A Modification of Linebarger's Apparatus for Determining the Weight of Air.—My modification of the apparatus described in School Science of February, 1903, is as follows: For the can I used one of the tin bottles or cans in which chemicals are sometimes shipped, e. g., carbon bisulphide or ether. These cans being bottle-shaped with rather small mouths, do not need a top soldered on.

I soldered the bicycle valve into the mouth, inserting first a piece of sheet zinc bent to fill the extra space between valve and bottle mouth. The can was quickly made and gives good results. It is small enough to lie on the scale pan of an analytical balance, so that, if desired, greater accuracy in weighing is secured.

Findlay, Ohio. JESSE H. GARNER.

Determination of the Weight of Air Without an Air Pump.—A flask holding two to three liters is fitted with a one-hole stopper through which passes a piece of glass tubing, with a bit of rubber hose slipped over one end of it. The rubber tube is closed with a pinch cock. The weight of the flask when open is ascertained, and then as much as possible of the air removed by suction with the lips. The weight of the flask thus partially emptied of air is found. The difference between these two weights gives the weight of the air removed by suction. The pinch cock is now opened with the end of the rubber tube under water. The volume of the water which enters the flask is equal to the volume of the air removed by suction. The method gives sufficiently accurate results, and recommends itself on account of its simplicity.

Zeits. f. d. phys. u. chem. Unterricht. XVI, p. 288. E. GRIMSEHL.

BIOLOGY.

"That a considerable part of the carbon dioxide (25 to 50 per cent) usually ascribed to the respiration of seeds in experiments is really due to respiration of microörganisms" is stated by Prof. C. R. Barnes in an inter-

esting excerpt in the October number of the *Botanical Gazette*. He also states that the antiseptics used by Nabokich in these experiments (bromine and corrosive sublimate) did not depress the respiration of the seeds, but rather accelerated it. This emphasizes the importance of sterilizing seeds for such experiments, as recommended by some of the school text books.

The Embryology of Polypterous has at last been traced far enough to recognize in it confirmation of the view that it is a prototype of amphibian development. This note from SCIENCE (October 9) will interest all biology teachers who do not have access to the original report.

"A Few Good Books and Bulletins on Nature Study, School Gardening and Elementary Agriculture for Common Schools" is the title of Circular No. 52, Office of Experiment Stations, offered by the United States Department of Agriculture, Division of Publication.

L. M.

PHYSIOLOGY.

The Value of Competitive Gymnastics.—Under this caption the Baroness Rose Posse contributes a bright and pithy paper to the September number of the *American Physical Education Review*. She says: "Those who enter the gymnasium should be trained most thoroughly in that for which they have no natural aptitude, in order that they may derive the greatest benefit morally and physically. Yet those who train for competitive events are apt to neglect everything else to spend hours each day for many weeks before the contest in practicing one form of exercise. It may be the very thing that they should not practice. It will enable them to excel in that particular kind of movement, but it is almost sure to produce a one-sided or over-development which should detract from their value as representative gymnasts; for such men should be not only harmoniously developed, but in after life they should continue perfectly strong and healthy in every part."

On this principle, the authoress suggests an amendment of the requirements for entering competitive events, restricting competition to those athletes who have had "a systematic all-round training, with particular reference to the strenthening of the heart and lungs." The object of this training would be, not specialization, but the acquiring of the highest type of development and physical endurance.

She arraigns our present practices: "Granting all the importance that popular enthusiasm gives to athletic sports as a means of cultivating courage, class spirit, quickness, presence of mind, etc., the fact still remains that these qualities may be called forth by other forms of training, without the accompaniment of broken bones, bruised bodies, disfigured countenances and deformities. The body should be beautiful, and whatever mars or prevents the development of beauty should be discountenanced by those whose profession it is to prescribe for the body. If the mass of the people

are to be interested in gymnastics we must not prejudice them by showing them unpleasant things. The timid man would be justified in shrinking from undertaking a course of gymnastics as exemplified by the work shown in some gymnastic exhibitions. It is not edifying to see an ill-shapen man come tottering in from a long run to drop exhausted on the ground, there to lie gasping, while all the blood deserts his ghastly face. The spectator experiences a strong feeling of repulsion for the man and for what has produced such a loathsome spectacle. * * * When gymnastics produce faults they defeat their object. * * * Men overtrain when they continue to exert themselves after the effort is a weariness or worse still, a pain. If gymnasts could be trained to do remarkable feats without showing extraordinary signs of fatigue, a great part of the objection to competitions would be removed.

"In all competitive gymnastics, it has been said, there is danger of overdoing. Under the excitement of the moment the contestant is unconscious of the strain he is undergoing. He makes just one more effort, and starts the little break in the blood-vessel that later may cause his death."

Thus, excessive fatigue causes intermittent action of the heart. Permanent injury may follow, either to the valves or the heart muscle. Indeed, endocarditis has often been known to originate in immoderate muscular exertion. The most common form of diseased heart induced by overdoing is hypertrophy, or enlarged heart.

Physical training needs to be lifted above the level of amusement or competition. Physical trainers should "feel as much responsibility in caring for their pupils as doctors for their patients or ministers for the welfare of souls. * * * In order to raise the standard we must efface the popular impression that all gymnastic training tends to athleticism—that the experiment of physical training shall be dropped if the child seems to be weak. Gymnastics are primarily for the weak because the strong will work out their development unaided—they merely need guidance. The public should be led to see that he who has had gymnastic training has improved his disposition, has lost his bad temper, has gained presence of mind, has become thoughtful of others, has begun to question whether the opinion of others is not at least as good as his own. Such an one will wish to have his neighbor derive the same benefits that he himself has obtained; he will use his influence to induce some one else to improve his bodily condition, and so he becomes of real use to mankind. Is not that more praiseworthy than winning a Marathon race—and perhaps afterward dying of heart complaint?"

The author contends that contests for "personal aggrandizement or the putting of one school, one university, one system, above others" produce a pernicious moral effect, and that "gymnastics will never occupy its proper place among the sciences if the stumbling-block of professional jealousy is in the path of the workers."

Basket-Ball.—Is basket-ball one of the approved sports, exercises or gymnastic feats of your school? If so, listen to what Miss Lucile E. Hill, director of Wellesley College, says of this popular school and college game. She said that it was more important to have healthy mothers than healthy fathers and basket-ball should be stopped at once, so far as girls under the college age are concerned, and should be admitted among the sports for women of any age only under professional supervision. The physical effects upon young girls at a critical period in their growth into womanhood, the chances of permanent injury to beauty and health, the evil influence of such excitement upon the emotional and nervous feminine nature, and the tendency to unsex the player—for she declared that the competitive game, with its traveling about, its exhibitions before mixed audiences, and its cultivation of the win-at-any-cost spirit, was not womanly, and made neither for character nor refinement—were all urged against the game for young girls. For its vogue she blamed not so much those who reveled in play, as the school boards and the principals who permit and in some cases encourage it.

F. W. B.

Book Reviews.

A Text-Book of Inorganic Chemistry. By Dr. A. F. Holleman. Translated by Dr. Hermon C. Cooper. John Wiley & Sons. New York, 1902. 15x25 cms. 458 pages. $2.50.

The reviewer has read this book with pleasure and profit. He can do no better than quote with entire approval an appreciation of the book published in a recent number of a reputable scientific periodical. "This text-book combines the new achievements of physical chemistry with the mass of long established facts of inorganic chemistry so as to form a unified whole; it makes it unnecessary for beginners to get acquainted with the common phenomena of elementary chemistry by the study of one book written on the old plan, and then take up the independent study of those laws of physical chemistry, established by Ostwald, van't Hoff, Arrhenius and their disciples, as set forth in some other manual devoted to those subjects. All these features are combined by Holleman in a single graded course, making it a superior, up-to-date work. The translation by Dr. Cooper is satisfactory and free from ambiguity."

L. C. N.

Elements of Geology. By Joseph Le Conte. Fifth edition, revised and partly rewritten by Herman Le Roy Fairchild. 16 × 23 cm., XII and 667 pages. D. Appleton & Co., New York. 1903. $4.00.

Little need be said about this classic among college text books. The

present edition amply embodies such changes as the improvement in the bookmakers' art and the growth of geologic science demand.

Photographic illustrations have displaced many diagramatic cuts of former editions, and while under certain topics the text is wholly rewritten, notably in the classification of glaciers and their deposits and in the theory of earth genesis the paging, as well as the style of the author, has been preserved. In its present form the book fully maintains its position among the best general geologies.

W. E. Davis.

Correspondence.

MATERIAL FOR TRANSLUCENT SCREENS.

Editor School Science:

Your readers will probably be interested to know that the best material for translucent screens I have ever seen is the thin, white paper known to the trade as vegetable parchment. It is the kind used for the leaves of letter copying books. It should be wet and stretched by shrinking on a wooden frame just as drawing paper is mounted on the drawing-board when it is desired to do accurate work. I introduced it about six years ago into the lecture room service at the University of California, and it has proved itself decidedly superior to ground glass, tracing cloth, et cetera, but I have not seen it in use elsewhere. Yours very truly,

Arthur W. Gray.

ERRATA.

Owing to the author's not having had an opportunity to look over proof, the following errors in the November number are to be corrected:

On page 260, line 2, read "Mearns" instead of "Mearus."

On page 264, line 4 from bottom, read "if one studies," instead of "of our studies."

On page 264, line 2 in footnote, read "Harvard" instead of "Howard."

On page 266, line 5 from bottom, read "of ten" instead of "often."

On page 267, line 12 below table, read "devious" instead of "obvious."